

# GENETIC INTERRELATIONSHIPS OF DERMATOGLYPHICS AND FUNCTIONAL HANDEDNESS<sup>1</sup>

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INVESTIGATORS of the relationships of dermatoglyphics and functional handedness are in general agreement in finding slight but nevertheless real differences between the dermatoglyphics of right-handed and left-handed populations (BETTMANN 1932; BONNEVIE 1933; CUMMINS, LECHE, and McCURE 1931; LECHE 1933; NEWMAN 1934; KEITH's unpublished data; CUMMINS 1940; CROMWELL and RIFE in press). Left-handers are characterized by slightly less bimanual asymmetry than are right-handers, rather than by outstanding differences in total pattern frequencies. The lowering of bimanual differences in left-handers is especially noticeable in females and is apparent in both palms and finger-tips.

The investigation herewith reported is concerned with the ascertainment of possible genetic interrelationships of pattern development in palm and finger-tip areas with each other and with functional handedness. Assortative mating, pleiotropy, and linkage may each result in certain types of association between biological traits. Obviously, handedness and dermatoglyphics are seldom, if ever, used as a basis for the selection of mates in man, so we need not consider assortative mating further.

Pleiotropic genes result in correlations in the general population between the affected traits. As mentioned previously, several investigators have obtained such data for palmar and finger dermatoglyphics with handedness. WAITE (1915) made an exhaustive analysis of the finger prints of a population of adult males and found that positive correlations exist between pattern frequencies of different fingers. WENNIGER (1935) observed an apparent negative correlation between the occurrence of patterns in thenar and hypothenar areas of palms. KEITH (1924) and BETTMANN (1931) have made similar observations. CUMMINS in a communication to the writer previous to this investigation states his opinion to the effect that pattern occurrences in the thenar/first, second, third, and fourth inter-digital areas are positively correlated with each other and with transverseness of ridges, and also that there is a negative correlation between patterns in hypothenar and thenar<sup>2</sup> areas. No literature has been found dealing with correlations between patterns on palms and on finger-tips.

Linked genes result in inter-trait correlations within sibships, but not within the general population. Thus investigations dealing with the dermatoglyphics of right-handers as compared with left-handers selected from the general population tell us nothing concerning possible linkage relationships. RIFE (1941) obtained evidence for autosomal linkage of genes responsible for pattern

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<sup>2</sup> The term thenar as used in this paper includes both thenar and first interdigital areas.

D in the fourth interdigital area with those responsible for functional handedness. These data were obtained from 24 sibships. No other literature on linkage relationships between handedness and dermatoglyphics or between different dermatoglyphic features is available.

The data included in this report were obtained from 34 sibships, comprising a total of 181 individuals and 548 paired sibs. All the individuals were white, largely descended from northern European stock. Handedness was determined on the basis of testimony and the performance of several unimanual operations, including writing, throwing, sewing, shooting marbles and use of knife and spoon. Those performing one or more of these operations with the left hand were classed as left-handed, those performing all with the right hand were classed as right-handed.

In our analysis of the dermatoglyphics both vestigial and true patterns are classed as patterns. Only loops are included in the third interdigital area, and only D patterns in the fourth interdigital area. Finger-tips are classified as to presence or absence of whorls. Data are included for pleiotropy between the palmar areas with each other and with whorl frequencies on finger-tips. Linkage data are included for each of the palmar areas and whorls on finger-tips with handedness, as well as for the palmar areas with each other and with whorl frequencies on finger-tips.

#### PLEIOTROPY

Tests for association between traits were made with  $2 \times 2$  tables. When significant relationships were obtained, correlation coefficients were determined by the use of Thurstone's computing diagrams (THURSTONE et al. 1933). Table 1 shows the results of tests for association between patterns on the five palmar areas within single hands. Table 2 shows the results of tests for similar relations between the hands of individuals, and table 3 shows the results of tests for association between frequencies of whorls on finger-tips with pattern occurrence on each of the palmar areas. If the individual has patterns on one or both hands, he is included as patterned. An individual may have from none to ten whorls on finger-tips. In table 3 association between whorl frequency and palm patterns is determined by comparing the frequencies of whorls within palm patterned versus patternless individuals. This type of comparison could not be converted to an actual correlation coefficient by Thurstone diagrams. Whether a loop occurs in the third or fourth interdigital area depends to some extent upon the transverseness of the palmar ridges, third interdigital patterns being more frequently found associated with the distinctly transverse ridges. Thus association with patterns in the third interdigital area is in reality an indication of association with transverseness of ridges.

Note (table 1) that within single hands a negative correlation exists between patterns in hypothenar and thenar areas, in agreement with the observations of other investigators. Furthermore, positive correlations exist between each of the other four palmar areas, the highest correlations generally being between adjacent areas. The high correlation between areas III and IV and also II and III is indicative of a positive correlation between transverseness of ridges and

the occurrence of pattern D in the interdigital areas. This is in complete harmony with the observations of CUMMINS.

TABLE 1

*The frequencies of different combinations of patterned and patternless areas in single palms.  
 $\chi^2$  values are underlined when significant.*

	PATTERNS ON BOTH AREAS	PATTERN ON FIRST AREA, AB- SENT ON SECOND	PATTERNS ABSENT ON FIRST PRESENT ON SECOND	PATTERN ABSENT ON BOTH AREAS	$\chi^2$	r
*Hypothenar and thenar	8	133	37	184	<u>8.70</u>	-.40
*Hypothenar and inter- digital II	9	132	14	207	0.94	
Hypothenar and inter- digital III	53	88	88	133	0.18	
Hypothenar and inter- digital IV	37	104	69	152	1.03	
*Thenar and interdigital II	7	38	16	301	6.54	+.38
Thenar and interdigital III	21	24	120	197	1.28	
Thenar and interdigital IV	17	28	89	228	1.79	
*Interdigitals II and III	16	7	125	214	<u>10.65</u>	+.45
*Interdigitals II and IV	17	7	89	250	<u>21.38</u>	+.55
Interdigitals III and IV	67	74	39	182	<u>37.11</u>	+.57

\* YATE'S (1931) correction used in the calculation of  $\chi^2$ .

TABLE 2

*The frequencies of different combinations of patterned and patternless palmar areas, resulting  
from comparisons of right with left and left with right palms of individuals.*

	PATTERNS ON BOTH AREAS	PATTERNS ON FIRST AREA, AB- SENT ON SECOND	PATTERN ON SECOND, ABSENT ON FIRST	PATTERN ABSENT ON BOTH AREAS	$\chi^2$	r
Hypothenar and thenar	13	128	32	189	2.18	
Hypothenar and inter- digital II	12	129	11	210	0.46	
Hypothenar and inter- digital III	58	83	83	138	0.46	
Hypothenar and inter- digital IV	35	106	71	150	2.21	
*Thenar and interdigital II	6	39	17	300	2.97	
Thenar and interdigital III	25	20	116	201	<u>5.96</u>	+.20
Thenar and interdigital IV	15	30	91	226	0.40	
*Interdigital IV and III	17	6	124	215	<u>13.86</u>	+.48
*Interdigital II and IV	15	8	91	248	<u>16.88</u>	+.47
Interdigital III and IV	62	79	44	177	15.25	+.43

\* YATE'S (1931) correction used in the calculation of  $\chi^2$ .

When both hands of individuals are compared, similar but less marked relationships between palmar areas are found (table 2). Four show significant correlations, and of these the comparatively low correlation between thenar and third interdigital areas is the only one to show an association which was not manifested within single hands. Significant associations are shown between the occurrence of patterns in the second, third, and fourth interdigital areas, and the frequency of whorls on finger-tips. Since no other data showing relationships between whorls and patterns in these areas are on record, the writer made similar comparisons with the prints of the Cromwell series (CROMWELL and RIFE in press) and found the same type of association. No other significant correlations between whorl frequencies and palm patterns are indicated.

TABLE 3

*The frequencies of whorls on finger-tips of individuals having one or more patterns in the palmar areas, as compared with those lacking patterns.*

	WITH PATTERNS		WITHOUT PATTERNS		$\chi^2$
	FINGER-	FINGER-	FINGER-	FINGER-	
	TIPS	TIPS	TIPS	TIPS	
	WITH	WITHOUT	WITH	WITHOUT	
	WHORLS	WHORLS	WHORLS	WHORLS	
Hypothenar	668	212	687	243	0.99
Thenar	232	78	1123	377	0.00
Interdigital II	108	62	1247	393	12.86
Interdigital III	803	287	412	108	5.92
Interdigital IV	526	224	829	231	15.21

## LINKAGE

Tests for linkage were made by the paired sib technique of PENROSE (1935). In regard to hypothenar, thenar/first, second, and fourth interdigital areas, individuals were classed in two categories in respect to each area, those having a pattern on one or both hands and those lacking a pattern on both hands. Tests for associations within paired sibs pattern frequencies in these areas with each other and with handedness were made in  $2 \times 2$  tables (table 4). Sib pairs were grouped into four classes—those alike in both traits, unlike in both, and the two combinations of alike in one and unlike in the other. If two traits are linked, pairs alike in both traits and unlike in both should exceed pairs alike in one trait and unlike in the other.

Both whorl frequency and the direction of Line C are quantitative or graded characters. The graded character method of PENROSE (1938) was employed in linkage tests involving these traits. In this method,  $\phi$  indicates the degree of linkage, and a  $\phi$  value of greater than twice its standard error is considered to be significant. The effect of pleiotropy is removed by subtracting the correlation squared from  $\phi$  (see table 5).

Individuals were placed in the following four grades in respect to whorl frequencies: 0, 1-3, 4-6, 7-10. They were classed in three grades in respect to Line C—those having loops formed in the third interdigital areas of both

TABLE 4

*Paired sib combinations of traits tested for linkage with 2×2 tables.*

	ALIKE IN BOTH TRAITS	ALIKE IN FIRST, UNLIKE IN SECOND	UNLIKE IN FIRST, LIKE IN SECOND	UNLIKE IN BOTH	$\chi^2$
Hypothenar and handedness	196	143	112	97	0.94
Thenar and handedness	259	80	168	41	1.21
Interdigital II and handedness	295	44	186	23	0.47
Interdigital IV and handedness	243	101	118	91	11.47
Hypothenar and thenar	248	181	64	55	0.62
Hypothenar and digital II	270	213	36	29	0.007
Hypothenar and interdigital IV	212	151	104	83	0.38
Thenar and interdigital II	381	102	43	20	3.80
Thenar and interdigital IV	280	74	168	40	0.23
Interdigitals II and IV	292	168	44	21	4.37

hands, those having a loop in the third interdigital of one hand and in the fourth of the other, and those having loops in the fourth interdigital areas of both hands. Since Line C is abortive or missing in many palms, the number of pairs used in comparison involving Line C is considerably less than in the others.

TABLE 5

*Values obtained in linkage tests involving whorls and Line C, by graded character method.  
Also checks on other traits indicating linkage in 2×2 tables.*

	$\phi$	S.E.	$\frac{\phi}{\text{S.E.}}$	r	$\frac{\phi - r^2}{\text{S.E.}}$
Whorls and hypothenar	+ .05	+ .3	+ 0.16		
Whorls and Line C	+ .37	+ .21	+ 1.76		
Whorls and thenar	+ .06	+ .2	- 0.30		
Whorls and interdigital II	+ .55	+ .21	+ 2.60		
Whorls and interdigital IV	+ .06	+ .13	+ 0.04		
Whorls and handedness	+ .42	+ .13	+ 3.20		
Line C and interdigital IV	+ .59	+ .14		+ .57	+ 1.89
Line C and hypothenar	+ .02	+ .16	+ 0.12		
Line C and thenar	+ .22	+ .23	+ 0.93		
Line C and interdigital	+ .05	+ .26	+ 0.19		
Line C and handedness	- .08	+ .11	- 0.07		
Interdigital IV and handedness	+ .36	+ .10	+ 3.60		
Interdigital IV and interdigital II	+ .03	+ .21	+ 0.14		
Cumulative pattern and whorl frequencies with handedness	+ .57	+ .11	+ 5.18		

The cumulative frequency values of whorls and patterns are estimated on the basis of patterns in all palmar areas, except the hypothenar, and on finger tips of both hands. Whorl frequencies are grouped in the same four categories as for the other comparisons, while patterns on each of the four areas under

consideration are given a value of 1. Thus the cumulative patterns and whorl values of individuals range from 0 to 7. If an individual has patterns on each of these areas on one or both hands, and whorls on seven or more finger-tips, he is placed in grade 7; if fewer, he is classified accordingly. Hypothenar patterns are omitted because of their negative correlations with thenar patterns:

An examination of tables 4 and 5 shows associations between the following: handedness with pattern D in the fourth interdigital area, handedness with whorl frequencies, patterns in the second interdigital area with whorl frequencies, and pattern frequencies in second and fourth interdigital areas, and between the cumulative frequencies of whorls on finger tips and patterns on palms with handedness. The highly significant indications of linkage between handedness and pattern D are in accord with the earlier findings of RIFE (1941). As a further check, these same areas were tested for linkage by the graded character method, with a resultant highly significant relationship (table 5). The relationship between whorl frequency and handedness is also highly significant, although less than that between pattern D and handedness. The indicated relationship between whorls and interdigital area II is significant but not highly so. In view of the fact that patterns occur only rarely in the second interdigital area and that they occurred in only five of the 34 sibships included in this investigation, the test results should probably not be considered as conclusive evidence of linkage between these traits. The linkage relationships between areas II and IV were also tested by the graded character method and, as shown in table 5, no linkage is indicated.

#### DISCUSSION

Pattern occurrence in each of the palmar areas, transverseness of palmar ridges, and whorl frequencies on finger-tips all show one or more inter-correlations. Highest correlations are usually obtained within palms when single rather than paired palms are compared. Associations characteristic of autosomal linkage are shown between handedness and whorl frequencies on finger-tips, handedness and pattern D in the fourth interdigital area, and cumulative pattern and whorl frequencies on palms and finger-tips with handedness.

Questions may arise as to why we do not also find evidence of linkage between patterns in the second interdigital area and the direction of Line C with handedness, since both show positive correlations with pattern D in the fourth interdigital area. Patterns occur only rarely in the second interdigital area, and in the absence of complete correlation between patterns in the two areas, it is not surprising that evidence for linkage of patterns in the second interdigital area with handedness is lacking. The correlation between patterns in the third and fourth interdigital areas actually is largely a one way correlation. A loop is usually formed in the third interdigital area when Line C swings in a radial direction, whereas a loop is usually formed in the fourth interdigital area when it swings in an ulnar direction. In the presence of pattern D in the fourth interdigital area, Line C usually forms a loop in the third interdigital area, very seldom in the fourth. In the absence of pattern D, however, loops occur with not greatly different frequencies in the third and

fourth interdigital areas. Due to abortive conditions of Line C or its complete absence in one or both palms of several individuals, only 273 pairs were available for comparisons. In view of these circumstances, one would not necessarily expect indications of linkage between Line C and handedness to appear.

While both whorl frequencies on finger tips and patterns in the fourth interdigital area show evidence of linkage with handedness, they show no indication of linkage with each other. This need cause no concern, since genes conditioning each of the traits may conceivably be located on a single chromosome, the gene affecting handedness being located midway between genes affecting whorls and patterns. The techniques employed for testing linkage are not precise enough for the detection of linked factors with high crossover percentages. It is also possible that two independent pairs of factors may affect handedness, one of which is linked with genes affecting whorl frequencies, and the other linked with genes affecting pattern development in the interdigital areas. In view of the association manifested between whorl frequencies and interdigital patterns, however, the most likely possibility is that the genes responsible for the correlation between whorls and interdigital patterns are linked with genes determining handedness. This is borne out by the relations between cumulative finger whorls and palm patterns with handedness. Other sets of genes likely influence the development of different areas independently, thus partially accounting for the lack of complete correlation between them.

Findings from comparative anatomy and human embryology would seem to lend support to this latter view (WHIPPLE 1904; CUMMINS 1929). Pattern areas on palms and finger-tips, as well as on soles and toes, are homologues of the volar or walking pads of mammals. During embryological development these pattern areas are much more elevated than at birth. Although the phylogenetic record is incomplete, there is good reason to believe that the degree of pattern development is positively associated with the degree of elevation of pattern areas and that the evolutionary trend has been toward a reduction in degree of elevation with a corresponding decrease of pattern intensity.

These changes have not progressed uniformly in the various pattern areas or even in right and left hand, as attested by the well established differences in pattern frequencies. Mutations affecting specific areas could account for such differences, while mutations affecting genes having a common effect on area elevation would be responsible for the general evolutionary trend toward reduction in pattern frequencies. Genes having a general effect on the degree of elevation and pattern intensity seem likely to be responsible not only for the observed correlations, but also possibly to be linked with genes determining handedness. Such linkage relationships would be more easily detected in pattern D and finger-tip whorls, because of the comparatively high occurrence of patterns in these areas.

#### SUMMARY

Within single hands, negative correlations exist between the occurrence of patterns in hypothenar and thenar areas. Positive intercorrelations exist

between pattern frequencies in thenar and second interdigital areas, between pattern frequencies in the second, third and fourth interdigital areas, and between the transverseness of ridges and interdigital pattern frequencies.

Within individuals, positive correlations exist between pattern frequencies in the second and fourth, the second and third, and the third and fourth interdigital areas. Frequencies of whorls on finger-tips are positively associated with pattern frequencies in the second, third, and fourth interdigital areas.

Paired sib comparisons show associations characteristic of autosomal linkage between factors responsible for D patterns in the fourth interdigital area with handedness, for whorl frequencies on finger-tips with handedness, and for combined whorl and pattern frequencies on finger-tips and palms with handedness.

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